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Distinction between the concepts of mathematical and logical modeling[*]

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Разграничение понятий математического и логического моделирования[***]

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Introduction. Technologies of mathematical and logical modeling of problem solving according to the existing practice of their distribution are divided into two areas: widespread mathematical modeling and infological modeling which is currently underdeveloped, especially for sophisticated systems. Fundamental differences between these technologies, in particular for the machining preproduction, are that logical modeling is informationally and logically related to organization systems, and mathematical modeling is associated with control processes in the organization systems. Logical modeling is used to operate with geometric objects in the technological schemes of their interaction through basing methods, geometric shaping in a static (ideal) setting of the corresponding schemes. Mathematical simulation is used to operate material objects in the control processes of their transformations through cutting methods, i.e. imperfectly, considering heterogeneous errors. Between the organization systems under study and management processes in them, there are information and logical links of their organic unity, which deny their separate consideration. In the information deterministic technology for solving problems of a high-level automation, the distinction between the concepts of "mathematical" and "logical" modeling is relevant; it has scientific novelty and practical significance.
Materials and Methods. To characterize the properties of the concepts of "mathematical modeling", "logical modeling" and the knowledge functions resulting from the formulation of these concepts, fundamentally different methods and appropriate tools are used. The differentiation of the concepts under consideration is based on the differentiation of technologies (methods, appropriate tools, algorithms, operations) for solving applied problems of any knowledge domain.
Research Results. The ideas of "logical modeling" and "mathematical modeling" are conceptual general-theoretical notions with invariant properties required for solving practical problems of any application domain. In accordance with the distinction between these concepts, the problem solving technologies are divided into two types: system engineering technology – in the organization of information object systems, and

Введение. Технологии математического и логического моделирования решения задач по существующей практике их распространения распределяются на два направления: широко распространенное математическое моделирование и информационное логическое моделирование, которое в настоящий момент развито недостаточно, в особенности для сложноорганизованных систем. Принципиальные различия этих технологий, в частности для подготовки производства обработкой резанием, в том, что логическое моделирование информационно и логически связано с системами организации, а математическое — с процессами управления в системах организации. Логическое моделирование используется для оперирования геометрическими объектами в технологических схемах их взаимодействия методами базирования, геометрического формообразования в условиях статической, т. е. идеальной настройки соответствующих схем. Математическое моделирование используется для оперирования материальными объектами в процессах управления их преобразованиями методами обработки резанием, т. е. неидеально с учетом функционально различных погрешностей. Между рассматриваемыми системами организации и процессами управления в них существуют информационные и логические связи их органического единства, отрицающие их раздельное рассмотрение. Для информационной детерминированной технологии решения задач высокого уровня автоматизации разграничение понятий «математическое» и «логическое» моделирование актуально, обладает научной новизной и практической значимостью.
Материалы и методы. Для характеристики свойств понятий «математическое моделирование», «логическое моделирование» и функций знаний, следующих из формулирования этих понятий, используются принципиально различные методы и соответствующие инструментальные средства. В основу разграничения рассматриваемых понятий положено разграничение технологий (методы, соответствующие средства, алгоритмы, операции) решения прикладных задач какой-либо предметной области знаний.
Результаты исследования. Понятия «логическое моделирование» и «математическое моделирование» являются концептуальными общетеоретическими понятиями, обладающими инвариантными свойствами, которые необходимы для решения задач практики какой-либо предметной области. В соответствии с разграничениями рассматриваемых понятий, технологии решения задач подразделяются на два типа: технология системной инженерии — в системах организации информационных объектов и технология

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system science – in the management processes of transformation of the corresponding material objects. These areas should exist in the information and logical link of their organic unity.
Discussion and Conclusions. The author distinguishes between the concepts of "logical modeling" and "mathematical modeling", which is a key condition for a successful transition to the deterministic information technology of a high-level automation in solving practical problems of any knowledge domain, for example, of the production design machining.

системотехники — в процессах управления преобразованиями соответствующих материальных объектов. Эти направления должны существовать в информационной и логической связи их органического единства.
Обсуждение и заключения. Автором разграничены понятия «логическое моделирование» и «математическое моделирование», что является важнейшим условием успешного перехода к детерминированной информационной технологии высокого уровня автоматизации в решении задач практики какой-либо предметной области знаний, например, технической подготовки производства резанием.

Keywords: production design engineering, cutting, system analysis, information technology, decision modeling, system science.

Ключевые слова: техническая подготовка производства, обработка резанием, системный анализ, информационная технология, моделирование решений, системная технология.

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Introduction. The main concepts of systems engineering as a creative technology for the integrated solution to engineering and organizational and management tasks are described in [1]. It is noted that the extremely high complexity and variety of large-scale highly automated systems significantly complicates the use of exclusively mathematical tools to determine them. The systems engineering concept was formed as part of the practice of successful development. However, this paper has come out with a change in the literal translation of the concept of "systems engineering" to the concept of "system science". Further, the system science was developed as an independent field of knowledge. Functions of the system science include management of the transformation of material objects in the corresponding systems of the organization. After the introduction of the concept of "system science", systems engineering in our country as a conceptual breakthrough competitive information technology for creating large complex powerful information systems was largely lost. The development went in the direction of designing control technological processes in organization systems through functionally different methods and means of the mathematical apparatus.

Functionally different aspects of the approach to system science in the cognition of the domain knowledge base for seven levels of the hierarchy of its basic objects of various types are described in [2] as an example of production design engineering (PDE) by cutting throughout its cycle.

Functions of systems engineering technology include the organization, on an invariant basis, of powerful deterministic systems for logical information modeling of the solution to a possible set of problems in models of basic knowledge objects and databases of their solutions with the issue of design documentation. Insight into the papers [3–13] marks that the direction of systems engineering technology is widely developed in terms of information and software for information processing systems on a computer, as well as in functionally different management. In the machining PDE, the development has gone towards translating traditional knowledge into an electronic form for computer perception. On the basis of such transformations of the knowledge form, ineffective dialog systems have been organized that do not have access to CAD systems for solving problems of low-level automation practice. System science is widely developed.

Deep properties of concepts are given in [14]: "... one of the human consciousness attributes is the ability to apply previously accumulated knowledge to solve emerging logical problems"; "... a concept can also be defined as a certain linguistic construction that has a certain meaning, that is, a figurative content". Ib.: "The object under study is called an original, and the object investigated instead of the original one to study certain properties is called a model". Ibid: "Modeling is a method (or process) of studying the properties of original objects through examining the corresponding properties of their models".

If the properties of a real object are described in words, a mathematical formula, a drawing or a diagram, i.e., are formalized in a model, then such a model can be called an information one. Only knowledge of an informational nature is suitable for computer processing. A systematic analysis of knowledge on systems engineering technology is difficult to understand, but its results are informative and at the same time concise. Proceed from the need to embed formalized concepts in the structure of basic knowledge objects of various types of application domain, the content of con-

cepts should achieve maximum precision. The author's updated interpretation of the existing and new concepts is most important.

Materials and Methods. We introduce the updated concept of system principles. System principles are informational logical statements of the approach to solving the problems of analyzing technological systems, processes of functionally various purposes under the conditions of respectively static, dynamic setting, verified through the multiple practice of their application.

Next, we formulate system principles.

1. A necessary condition for a sequenced technological procedure of functionally various nature (engineering, physical, chemical, biological) of transformation of any object is the presence of a control system. The transformation management function is always specific, implemented in relation to the corresponding technological system. Consequently, a necessary condition for the existence of a transformation management system for an object is the existence of an appropriate technological system for its organization. We refer to the well-known and fair saying: "You can't manage a poorly organized object well".

At that, the concept of "organization" is further considered on the basis of compliance with the concept of "structure" in various aspects of its interpretation using the example of the machining PDE. The author has organized the solution to the PDE tasks on a possible set of workpieces, production facilities, machine tools, cutting tools, devices for installing cutting tools and production facilities; we use the notation {…}— a set.

We introduce the updated concepts.

• A structure is a construction (organization) of an object determined by decomposition methods as part of structure elements and synthesis methods through superimposing relationships between structure elements of different levels and one level of structure, which are based on design quality parameters of the main elements of integration, structure disintegration.

• **The main elements of structure integration, disintegration** are the elements of knowledge that characterize functionally various elements of the object structures ({details}) of the stage of designing preproduction (DPP) and objects ({primary blanks}) of the stage of production design engineering (PDE), as well as links between structural elements.

• **The design quality of the main elements of integration, disintegration in the structure of objects ({details}) of the DPP stage and in the structure of objects ({primary blanks}) of the PDE stage** is a function that should be unconditionally executed for a set of design quality parameters that characterizes a possible set of various properties of objects in their distribution among various of the object structure elements and the relationships between the elements of the structure of objects.

• **The basic object of knowledge** is material that is defined on the basis of the concept of "structure" in the organic unity of its information and logical connections with the concepts of "content" and "form", which deny their separate consideration.

• **The information "slave" (main) transformation object** is a primary material whose knowledge information display is possible only in a unified environment of one level of the structure of the technological scheme based on the interaction of structural elements of a "slave" object in a general case with the group of structural elements of a "master" object, and controlled transformation is realized only in the corresponding processes.

2. The conjugation of the "slave" and "master" objects of interaction through superimposing the links of its functional purpose from the side in a general case of a group of structure elements of the "master" object to the functional elements in the structure of a "slave" object allows us to determine the method for converting the "slave" object and the properties of the mating objects.

3. The information technology operations for solving the problems of the DPP and PDE stages are distributed into the main and auxiliary operations. We distribute the main operations in two directions — technological and designing ones. In main operations, we consider types of support for engineering systems for organizing work machines and work machine systems for cutting. In auxiliary operations, we consider types of support for engineering systems for controlling working machines for cutting. Auxiliary operations of the design direction should be assigned to the corresponding departments of the DPP stage. Types of support for engineering systems of organization and management are determined in the information and logical communication, consisting of organizational, methodological, logical, normative, informational, software, and technical.

4. The objects of transformation in the machining PDE are material objects {details, assembly units of products} of the DPP stages and {primary blanks, blanks} of the PDE stages. Geometric objects are ideal ones corresponding to the material objects of the DPP and PDE stages.

The structure of the objects of the DPP stage is considered in accordance with the composition of the work functions performed by each of the four groups of structure elements [15]. The work functions of the structural elements

in this paper are determined by combining the basing functions with other functions into their possible combinations. The composition of the functions includes basing, directing, torque transmission, division and fixation.

The structure of the objects {primary blanks blanks} of the PDE stage is considered in accordance with the composition of the work functions performed by two "slave" objects of interaction in the corresponding process flowsheets. The composition of the functions includes basing, basing and geometric shaping of the structural element.

5. The knowledge of geometric objects is based on the distribution of the basic elements (integration, disintegration) of the structure of production objects (primary blanks, blanks), respectively, and their design quality parameters through the sequence of transformations by cutting into groups:

- linear and angular dimensions of elementary simple and superimposed (simple, complex) form elements;
- macrogeometric shape of form elements;
- microgeometric shape (height of microroughnesses) of form elements;
- positional relationships for the execution of the functions of the mutual arrangement between the centers of the coordinate systems of functionally various groups of form elements in the structure of one object and various objects, as well as between the coordinate "geometric" axes of the "basic" and "superimposed" simple and complex form elements:
- functionally different relations for the execution of functions of relative position, for example (alignment, perpendicularity, parallelism) between the coordinate "geometric" axes of the form elements in their various groups of the structure of one object and between the coordinate "guide" axes of the process flowsheets of interaction of various objects.

6. We consider information models of organization systems on the basis of the following principles:

• timeless, in space, in a general combination of information and logically connected coordinate systems;

• ideally under the conditions of static adjustment of process flowsheets of interaction of information objects without using any forces, but considering the time factor under the conditions of dynamic adjustment of transformation control processes of the corresponding real "slave" objects;

• taking into account functionally different errors in the design quality parameters of the main elements of integration, disintegration of the structure of real "slave" objects.

7. We consider the technology of information logical modeling of solving practical problems by methods and appropriate means on the basis of the following principles.

7.1. We operate with a functionally defined system of concepts, each of which has its own formalized designation. Problem solving is based on the distribution of the structure of information models for the basic objects of knowledge in two parts of information: invariant, typical object-oriented parametric. Information models of basic knowledge objects of a higher level are organized on the basis of typical object-oriented parametric parts.

7.2. In typical object-oriented parametric parts of information models of basic knowledge objects of all types, the tasks of unconditional maintenance of design quality for the basic elements (integration, disintegration) of the structure of "slave" transformation objects are solved. Problem solving is always specific within the record of information. It is performed in accordance with the integrated algorithm in the technique of mapping and converting the domain knowledge base in the hierarchy of the classification structure of its basic knowledge objects at seven levels of structure; in accordance with the graph of the structure of the basic object of knowledge of any type.

7.3. In the decision databases defined on the invariant parts of information models of the basic objects of knowledge, in the general case, within the framework of structure transformations, work functions and parameters of various properties, the problems on optimizing the material and labor resources are solved.

7.4. We use the means of a system analysis of knowledge: conceptual ideas, set theory, graph theory. Conceptual ideas are "reflection", "transformation", "structure", "set", etc. Graphic tools are formalized designations of concepts embedded in the structure of basic knowledge objects. Set theory is a branch of mathematics that includes the concept of a "logical operator" for expressing assertions through imposing connections between formalized concepts, etc. Graph theory is a branch of mathematics that studies, in particular, "structure graphs" used by "Venn diagrams" for imposing relations between functionally uniform objects of consideration.

8. Logical information modeling of the basic objects of knowledge of functionally various types of any subject area, which is based on the system analysis principles for establishing a continuous, flexible integral algorithm in technology (methods, appropriate tools, algorithms, operations) for mapping knowledge, reveals all "flaws" of the amorphous (outside the structure) mapping of knowledge. Here, the target properties of the concept of "logical modeling" and the knowledge functions following from its formulation are important.

9. We consider mathematical models of control processes on the basis of the following principles:

• in accordance with the algorithm in the technology for solving problems of the knowledge domain;

• considering the information and logical links of the integral organization systems and management processes, parameters of time and space;

• not ideal under the conditions of dynamic tuning of interaction between real objects of a technical, physical, chemical, biological nature using various forces.

Various errors of the design quality parameters of the main elements (integration, disintegration) of the structure of real "slave" objects determined by experimental measurements in the process of their transformation are subject to accounting with their subsequent regulatory ordering to the calculated maximum permissible accuracy deviations to use in the reference documentation in the form of recommended technical design conditions.

10. The mathematical modeling technology of solving practical problems is considered on the basis of the following principles:

• operating with a functionally defined system of parameters, each of which is indicated by its own symbol;

• using various techniques and appropriate means of the mathematical apparatus;

• problem solving is always specific within the limits of information recording; it is performed as a parameter transformation (parametric models).

Research Results. Under the control of the person's goal-setting function [16], the concepts of "space - time", "organization systems - control processes", "logical modeling - mathematical modeling" are considered on an invariant basis with respect to any knowledge domains in their systemic information and logical connection. The identifier of their connection, which has the property of integrity, which denies separate consideration, is the concept of "Content of the transformation of "slave" objects" within certain engineering control elements [17].

The system engineering technology defined by the author for the machining PDE in the practice of contract works as an information technology for its domain knowledge base can be extended to pressure, welding, functionally various management, computer processing of information.

Discussion and Conclusions. The machining PDE stage is, of course, a large complex information product which includes both functionally various systems for organizing its information products and their management process. Multiple attempts to solve the problems of PDE automation throughout the whole cycle of its practice were unsuccessful due to the logically informal presentation of the source data and the presence of significant difficulties characteristic of large complex automated systems when implementing design solutions using only a mathematical apparatus.

On the ground of the logical incompleteness of traditional descriptive knowledge, the transition to the technology of their mapping into knowledge of an informational nature to achieve a sufficient level of automation of solving practical problems is essentially difficult or impossible. To establish a continuous and flexible integrated algorithm in a deterministic technology for solving problems of a high level of automation, methods and tools of system engineering of information logical modeling are required.

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